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MANAGEMENT CONTROL SYSTEMS

James Farmer

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# 6 MANAGEMENT CONTROL SYSTEMS, 7 NA

10 by James Farmer* 8 NA

The RAND Corporation, Santa Monica, California 9 NA

This paper describes management control systems by considering the management functions of control and decision making. These are related to the objective and functions of a management control system. The problem areas of performance measurement, the language barrier between manager and system, and the costs of such systems are described. An introduction to feedback control systems is included as an appendix.

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# I. INTRODUCTION

"Management control systems" has become another popular phrase. Researchers in computer sciences, engineering, and management claim management control systems are a proper subject for their interest. Management reaction varies from wild enthusiasm to utter antipathy, often colored by a fear of managerial unemployment. Megabuck price tags makes skeptics of the optimistic, and the problems of building a useful system staggers the well-read scientist. Can we then dismiss management control systems and check on them in another decade or so? No. A recent business publication(1) tells how Pittsburgh Steel Company and IBM are

> ...activating an electronic data processing system known as "total systems concept." The aim of TSC is to handle every number in the company except the address on the letterheads.

Some of the objectives of such a system are inventory savings, customer service improvement, halting the growth of the clerical force, lower costs and higher profits, and the time and tools to examine perspective improvements. If only a few of these objectives can be met, then competitors had better keep their eye on the improving technology.

But what exactly is a management control system? Before we tackle this problem directly, let's consider some definitions.

## SOME DEFINITIONS

Drs. Koontz and O'Donnell(2) defined control saying: "The control function includes those activities which are designed to compel events to conform to plans."* They elaborate saying: "It is thus the function whereby every manager, from the president to the foreman, makes sure that what is done will be that which is intended."** For the scientist control is defined as "...a system or device which exerts a restraining, governing or directing influence."(3) Both agree: Control is a process. As such, control can take on many forms and means different things to the foreman on the assembly line, to the electronics engineer designing machine controls, and to the manager.

The word management excludes most control systems from our immediate consideration. Specifically it excludes the whole family of process controls such as found on assembly lines and in refineries and most of the operational control systems such as found in railroads and electric power companies. Unfortunately the latter sometimes take on the aspects of a management control system since the data for managerial decisions often comes from the control system and these decisions are implemented by the same system. As these control systems become more sophisticated, the boundary becomes very hazy indeed. We turn our attention, however, to those systems which aid a manager in the decision process, particularly at the higher levels of business activity.

System is a difficult word to define, but not because Webster doesn't give a definition. Webster says: "1. An assemblage of objects united by some form of regular interaction or interdependence; an

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*Page 37, Ref. 2.
**Page 587, Ref. 2.

organic or organized whole. 2. The universe. The body considered as a whole."[4] System can be used for anything from a flashlight* to a vast combination of men and machines like SAGE.** Since the word gained stature as a status symbol, it has been liberally sprinkled throughout most writing, and as such has lost much of its meaning. The only thing it means here is that which controls has more than one part and these parts are in some way related with each other.

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*Now known as a portable electrical lighting system.

**Semi-Automatic Ground Environment system. A system about twice as large as all of General Motors which provides defense against a manned bomber attack.

## II. AN IMPLICIT DESCRIPTION

Management control systems could be described by discussing the physical hardware--the computers, communication equipment, and so forth, or by discussing the algorithms or programs and functional descriptions. But to better understand what management control systems are, let us first consider decisions and control. We can examine what is the objective of a management control system and what are the criteria for measuring the performance of the system. Having described the environment, the "input" and "output" of a management control system, we have, in one sense, described what a management control system is. In the physical sense a management control system is hardware--a computer, a teletype machine, a photographic file, a computer program, and so forth. But as management students we are not as concerned with a description of a management control system in terms of nuts, bolts, and punched cards, as we are with what it can do. This implicitly answers the question "What is a management control system?" Then we can consider the areas where technology limits what can be done.

## III. TYPES OF CONTROL

It may be helpful to classify the various types of control found in business. We can divide control into six categories. They are neither exhaustive nor mutually exclusive, but approximate the classes of resources available to the firm.

- Personnel Management Control - The function of personnel management control is to see that the firm's personnel resources are best applied to meet the firm's objectives. The very fact that the controlled element is the people staffing the firm make this area most subjective and difficult to control, particularly when the output is a product of men's minds rather than their hands.

- Financial Control - The function of financial control is to assure that money, as a resource of the firm, is best applied to meet the firm's objectives. The control is exercised over dollars. Because one objective of the firm--the profit objective--is measured in dollars, financial control receives special emphasis since the contribution of all resources may be measured, in part at least, in dollars. However, financial control is not the only type of control. Generally financial control is easier to exercise than other types of control because it is readily measurable.

- Inventory Control - Inventory represents both a potential contribution to the firm and past costs. For this reason inventory control--the size, distribution, turnover rate, etc.,--is important. Because of recent advances in operations analysis techniques and computer technology, inventory is now amenable to control and represents a significant extension of the control process.[5]

- Production Control - Control of the production process can vary from an occasional "How are things going" to a computer model of the entire production process with constant comparison between the predicted performance and actual performance. Excellent examples of production control include automated oil refineries, electrical power generation and distribution systems, and some assembly lines. PERT is also primarily a production control technique.[6] The firm's objectives are stated in terms of desired outputs and constraints, and the production control system attempts to match that output within the constraints. Production control includes quality control since the output can be specified not only by amount, but also by a range of accepted quality.

- Technical Control - Control of the firm's technology, an increasingly important resource, is very difficult. It consists of both the written resources and the information which the scientific and technical personnel have.

Firms have generally concentrated on financial control and have been satisfied to have little or no explicit controls over the other resources. Chamberlain[7] recognizes the changed form of business:

> An initial amount of financial control quickly produces decided results in reducing the costs of running an organization. But progressive increases in the amount of financial control do not produce comparable increases in efficiency, however, and a point is soon reached beyond which further financial controls do not pay off.
>
> Increasing technical control has a somewhat similar effect; it will produce increasing results until some maximum is reached beyond which creativity begins to be stymied.

Because financial control is the simplest type of control to "automate," and because of the preoccupation with financial controls, many management control systems are merely the adaptation of computers to the accounting system. This is not management control in the full sense.

There is another classification of control by the technique employed. These types include:

- Continuous Control - In this case the output is continuously measured and this information fed back to the control elements.* Most process controls fall in this category. Real time inventory control is also continuous.

- Sampled Data Control - If the output is measured only at intervals, either periodic or random, and the information is used for control, this is called sampled data control.

- Aggregative Control - If the output is measured and the results accumulated, and this aggregated information fed back to the control elements, this is called aggregative control. Most accounting systems provide aggregative control.

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*Feedback is defined in the appendix.

Another useful classification of control is by the amount of delay (positive, zero, or negative) in the feedback. These types include:

- Delayed Control - The information fedback is delayed in time from the output. This delay may either be stabilizing or destabilizing to the system. Accounting is a delayed control.

- Real Time Control - The measurement of output and comparison with the reference level (desired output) are done simultaneously. Control systems used in electric power generation and distribution systems and oil refineries are usually real time control systems. Librascope's Operational Control system is a documented example of a real time system.*

- Predictive Control - Because of the dynamic characteristics of the external environment, it is often desirable to compensate for internal delays by comparing the predicted output at some future time to the reference level. This type of control is most effective where the production process is well defined and takes a relatively long time.

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*The system is described in detail in Ref. 8. Even though the author feels that the need for an integrated system is axiomatic, the article is a good case history.

## IV. DECISIONS AND DECISION-MAKERS

### TYPES OF DECISIONS

Since the purpose of management control systems is to assist in the decision making process, it is important to recognize that there is a spectrum of types of decisions. Authors have divided decisions into two classes, programmed decisions and nonprogrammed decisions. Actual decisions do not uniquely fall in one class, but for our purposes it is helpful to distinguish between the two types. Herbert Simon[9] describes the two classes:

> Decisions are programmed to the extent that they are repetitive and routine, to the extent that a definite procedure has been worked out for handling them so that they don't have to be treated *de novo* each time they occur. The obvious reason why programmed decisions tend to be repetitive, and vice versa, is that as a particular problem recurs often enough, a routine procedure will usually be worked out for solving it.

An appropriate algorithm will yield programmed decisions, and when people say that "computers make decisions" they are generally speaking of programmed decisions. The models which operations analysts use to select inventory levels, staffing levels, distribution patterns, production allocations, and so forth are all algorithms which yield programmed decisions. (The decision to "override" such a solution is a nonprogrammed decision.) Insofar as the factors affecting the decision can be quantified and the procedure for the decision be made explicit these decisions can be made by a computer.

Some progress has been made on nonprogrammed decisions. Heuristic programming or artificial intelligence offer approaches to this problem. In the former case the results of experience are used to modify the algorithms or program and the computer can, in some sense, be said to "learn." Although Simon is enthusiastic about this approach, he would agree much research work must be done before it is applied to business decision-making.

THE DECISION-MAKING PROCESS

A mathematician likes to consider a decision as a simple choice between courses of action. But decisions cannot be accurately characterized by this simple choice. Simon[9] believes there should be a three phase "decision-making process."

> The first phase of the decision-making process--searching the environment for conditions calling for decision--I shall call intelligence activity (borrowing the military meaning of intelligence). The second phase--inventing, developing, and analysing possible courses of action--I shall call design activity. The third phase--selecting a particular course of action from those available--I shall call choice activity.

In a previous paper[10] this was considered a sequential decision process with two types of decisions:

- o A terminal decision. This is a selection of the course of action, the decision, which will terminate the sequential decision process.
- o A continuation decision. This is a decision between continuing to obtain information, with attendent time delay and cost, and making a terminal decision.

Commenting on the process:

> In practice the continuation decision is often made through reluctance to make a decision rather than a conscious consideration of increasing the accuracy of the decision by using additional time and accepting the cost of additional information.

Obviously timing of decisions is important, and difficult to define. This consideration alone precludes computer solution to a large class of decisions: The factors affecting timing are more subjective than the decision itself. Most of the decisions in business are programmed decisions and as such could conceivably be automated. However, the most important decisions are nonprogrammed, and most will not be amenable to automation in the immediate future. Jacoby[11] comments on the role of middle-management saying: "Automation will change the nature of the tasks of the middle manager rather than render him a useless appendage." Automation of programmed decisions can give the middle manager the additional time he needs for more important nonprogrammed decisions and that important function of communicating with the firm's staff.

## THE DECISION-MAKING ENVIRONMENT

Figure 1 is a heuristic diagram used by Jack Carne* to illustrate the decision-maker's environment and the flows of information. The decision-maker needs three types of information:

- Intelligence Information: Information is needed about the external environment. This includes knowledge of the competitors' activities, the general economy, government activities, and similar types of information.**
- Status: This includes knowledge of the firm's activities, the available resources--personnel, equipment, and financial, plans, and objectives.
- Policy Constraints: A decision-maker does not have complete freedom in his choices of action, but rather has only a limited set of choices. The limitations are policy constraints.

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*Of the RAND Corporation in unpublished works. The diagram has been modified for the business decision-maker rather than a military commander.

**Business intelligence systems are often confused with business information systems. Intelligence does not include "status information" of the organization.

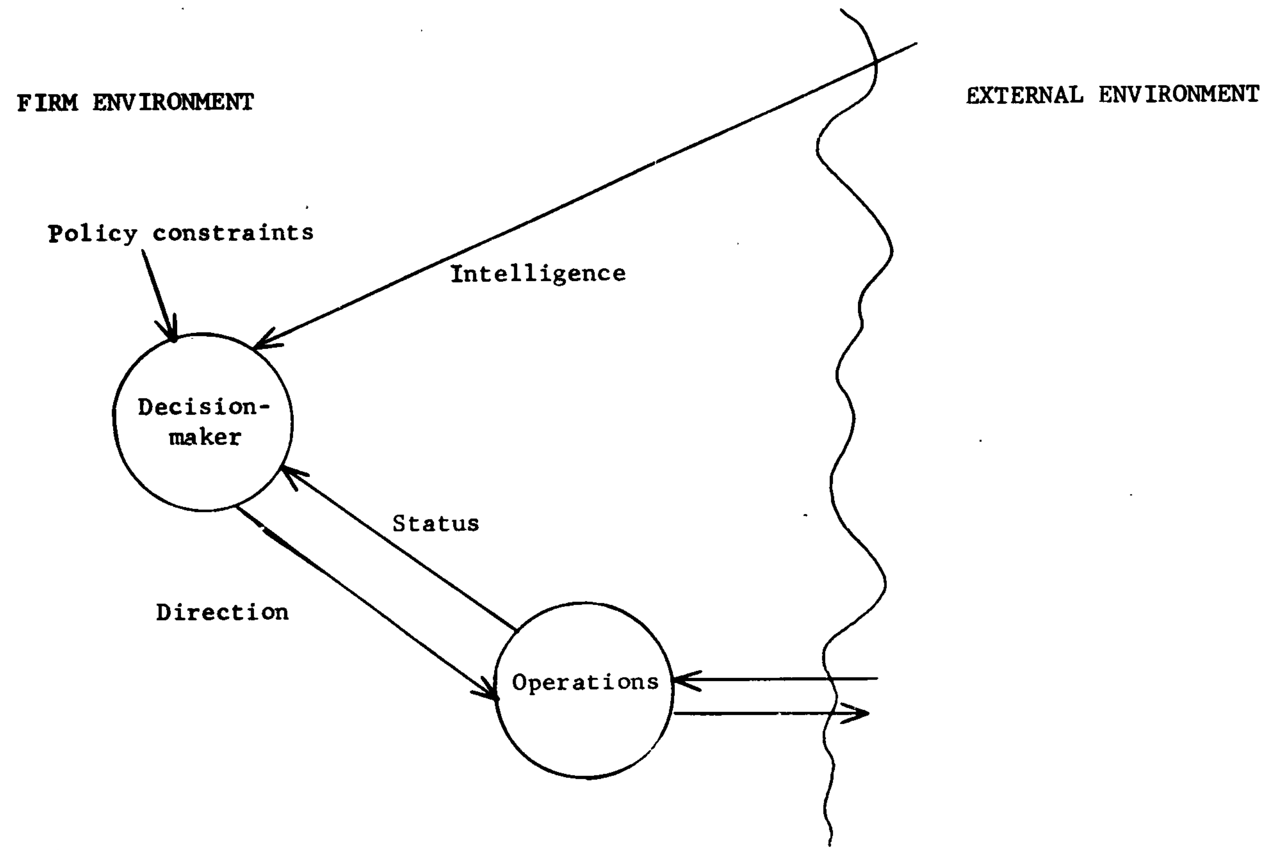


Fig. 1 - Decision-making environment

The decision then takes the form of direction. The direction can be the result of control on this level or reference (desired) level for the next lower level. As Carne indicates, operations interact in some undefined way with the external environment.

Control requires that a performance measurement (a measurement of output) be made and compared with some reference level. This requires planning in a specific sense before the decision can be classed as a control decision. Insofar as plans are vague and undefined, control becomes meaningless and nonexistent.

## V. OBJECTIVE AND FUNCTIONS OF THE MANAGEMENT CONTROL SYSTEM

### THE OBJECTIVE

With those definitions, the objective of a management control system can be stated. The management control system should make those control decisions that can be programmed and provide the information (or data) to assist the manager in making nonprogrammed decisions. Although this objective can be stated simply, fulfilling it is a difficult task. First, scientists have little insight into the management process. Although great strides have been made into evaluating various alternatives by such techniques as "cost effectiveness", many decisions are still made on the basis of impressions, feelings, and "other factors". The current selection of the TFX fighter by Defense Secretary McNamara is an example of a decision made on "other factors". Exactly what decision-making process managers use is still an open question. Second, how can you decide what information is important and if it should be presented? Looking at past decisions the answers may seem apparent, but future decisions may require completely different information.

Some management control systems have failed: Managers found the output was not what they needed and they didn't use the system. This is failure by definition.

### FUNCTIONS OF A MANAGEMENT CONTROL SYSTEM

There are some basic functions found, in varying degrees, in all management control systems. Like many of our other classifications, these also are not mutually exclusive or exhaustive. They correspond more to the divisions of academic interest than to any natural classification.

Modeling - In any control system there must be a model of the firm. This model may be so simple and unsophisticated that it is difficult to recognize as a firm model. It may emphasize only one phase of the firm's activities as, for example, the accounting model. It is a valid model of cash flow and a record of the use of dollars as a resource. Alone it can be used in financial control, but it is only part of an integrated control system. The most sophisticated firm models appear in business games, such as UCLA's Taks Manufacturing Corporation game,[12] and in fully integrated control systems such as Pittsburgh Steel Company.[1]

Models have both exogenous and endogenous variables. One of the first problems is to chose whether the variable should be one or the other. Current demand may clearly be an endogenous variable - it is the orders a firm is receiving for its products. Predicted demand may be endogenous to the management control system, and hence can be obtained as an output, or it may be treated as an exogenous variable and be a required input. Generally as the model becomes more sophisticated fewer exogenous variables will be required. Since a computer, as such, has no "feel" for the data, many managers prefer key variables to remain exogenous or in some cases to review the computer's predicted values.

Data Storage and Retrieval - Most management control systems contain a management information system. The information necessary for either making programmed decisions or for nonprogrammed decisions must be available to the management control system. A management information system does some communication and data processing, but the most important function is data storage and retrieval. Even to prepare reports there must be some form of storage and retrieval. S. A. Spencer[13] studied management information systems and found several points where systems go wrong:

- o Information systems are not designed for the three levels of of management planning and control. (They omit top management).
- o The information system does not match the organization.
- o The system covers dollars, not information.
- o The system produces encyclopedias instead of brief, pointed reports.
- o Internal operations are covered extensively, but external factors are disregarded.

He recognizes that there are different information needs for the different levels of management, that the output must be designed to support the particular organization by giving the right information to the right people, that information includes something besides dollars, that reports must be brief, and that external factors should be recognized. One of the latent benefits of any management control system is that these questions must be considered and specific answers are required for system design. Although many management control systems, if we consider only the hardware, do not satisfy all of these requirements, they must be met by some source of information, or by guess.

The management control system must have sufficient flexibility and capability not only to be able to produce reports, but to retrieve specific information needed by the manager.

Unfortunately data storage and retrieval is one of the most difficult technical problems in designing a management control system and is expensive.

Communication and Data Processing - The heart of any management control system is data processing. The comparison for control, summarization and selection of information, computation for models, and communication all require data processing. Most management control system are sold on the basis of the data processing they will do, often accounting data processing. This is also the simplest function to perform--there is no question of the high state of development of our technology.

Communication in any complex organization is an important function which is often taken for granted by everyone except the man who pays the phone bill. It is true that much of the communication in a firm is direct conversation and informal telephone calls, but also a large part of any firm's communication is written communication. Much of this written communication is record communication. The Franklin Institute,(14) in studying military communications, found the traditional way of handling written communications is a severe limitation on a quick-reaction management capability. Managers like and need record communication, but the Army, for example, often requires days for a written communication to reach the addressee. One of the important functions of any large management control system is communication. Information should flow from one part of the organization to another without extensive delay for routine processing and transmittal. Furthermore the design of the management control system input-output has placed emphasis on communication as a function. Management deals with the flow of information and delay, noise, or misrouting can seriously degrade the management effort. A management control system can reduce the misrouting problem (i.e., send the right information to the right people) and radically decrease delay time due to transmission. Communication as a function should be most carefully considered in the system design.

## VI. PROBLEM AREAS

### PERFORMANCE MEASUREMENT

In order to control performance it is necessary to measure performance. If a management control system is used, performance measurement becomes an even more difficult problem since these measurements must be numerable, rather than a subjective feeling. (Some may argue that a person can reduce his subjective feelings to a number system, but experience in personnel management demonstrates how difficult this can be.) For example, with assembly lines the performance can be measured in number of items produced in a given period of time. Fine. However, measuring a performance like, say, "service" at the telephone company, is much more difficult. (It is now measured in waiting time for the customer.) Fortunately operations researchers have developed many quantitative performance measurements which can be used for control, and further research is extending our ability. But every manager should be aware of exactly what performance measurement is being used--often a substitute is used which does not measure the fulfillment of a firm goal.

Even when some performance measurement can be proscribed, like measuring the rate of return on investment for managers, emphasis may be placed on the factors which directly affect the measure, sometimes to the detriment of other firm objectives which are equally important, but less amenable to measurement. Suboptimization is an ever-present danger.

THE LANGUAGE BARRIER

Computers can, at best, speak only faltering English. Although large amounts of effort have gone into enabling men to communicate with machines, this remains a serious problem. There are three quasi-solutions: First, have only a preselected list of questions which the computer can be asked. Second, use a "translator", someone who speaks English and the computer's language. Third, both learn a common language. There are two well known examples of the latter. Many people (and machines) speak COBOL and FORTRAN. It is not inconceivable that even more universal languages will be spoken in the future. Iverson notation is an example of a programming language now being taught people and programmed for machines. The concept of vector and matrix is quite broad and business in the future may talk about the "Cash accounts vector" or the "customer accounts matrix." Selecting delinquent accounts may quickly be translated into "all customer vectors with a negative $10^{th}$ component."

The language barrier and handling natural language with a computer may be the greatest technical barrier to rapid advances in management control systems. However, advances in language translation, data retrieval techniques, indexing, and meta-programming are all contributing to the solution.

COSTS

Computers provide a tremendous reduction in the cost of computations. New and faster computers may reduce that even more. For this reason problems considered to be too costly to solve by hand are now considered commonplace. But this doesn't mean that management control systems are inexpensive. On the contrary most are exceptionally expensive. Whether they are too expensive for the savings that result is a question for each firm to decide. Since implicit savings are difficult to measure, there is no clear criterion for having a management control system. Reducing costs will be a prerequisite to any large scale use of computer technology in management controls systems.

## Appendix

## AN INTRODUCTION TO CONTROL SYSTEMS

An understanding of the mathematical concepts of control systems is useful for two reasons. First, the precision of mathematical definition helps to resolve the semantic problem of subjective discussion. Second, such models are the basis of automated control systems.

Two general types of control systems are recognized, the "open-loop" and the "closed-loop" or feedback system. In the open-loop system the control signal is fed into the controlled system and the output is a function of the control signal and all of the intermediate components. A typical example is the automobile engine. The control signal is the pressure put on the gas pedal. The output, or power, is a function of the type of gas pedal, the engine, the type of automobile and so on. Anyone who drives a Corvette after a Ford Falcon understands the disadvantage of this type of system--the resulting speed differs widely between the two automobiles with the same gas pedal pressure. Since the human can quickly learn the different input-output relationships, maintaining an accurate input-output relationship is unimportant. These systems are simple to operate, have fewer components than feedback systems, and may yield stable operation.

On the other hand, the feedback control system develops an error signal which is used to actuate the system. The

$$\text{Error} = \text{desired output} - \text{actual output}$$

This relationship will then correct for variation in the intermediate components. A simple example, and often used by authors, is the thermostat. The signal is roughly proportional to the difference between the desired temperature and the actual temperature. (In this case, the actuating current is generally "on" a larger percentage of the time when the weather is cold.)

Feedback systems permit the effect on the output of the performance of intermediate components to be measured and this "experience" to be used in determining the error and the resulting control signal.

Figure 2 shows a typical "open-loop" control system. Figure 3 shows a typical feedback control system. In both cases there is a reference input level. In the feedback system the input is mixed with the primary feedback. The primary feedback is a function of the output. These two signals determine the output of the control elements. If the performance of the controlled system varied without a change in the reference input, then the output would vary. This change in value would be fed back to the control elements through the feedback loop.

Figure 4 shows a control system having two feedback control loops. The primary feedback operates like the feedback loop in Fig. 3. The reference input level is determined by a secondary feedback from the external environment. The output of the controlled operations is but one of many variables in the external environment. This case is more typical of the control processes in a business environment. There are many feedback loops at the different levels of organization.

A large body of knowledge has been built around the mathematics

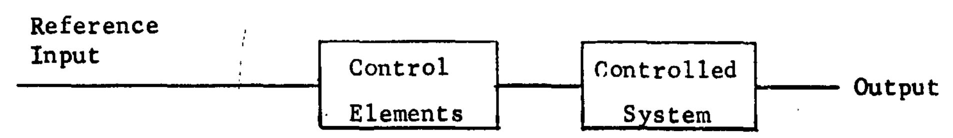


Fig. 2 - A typical "open-loop" control system

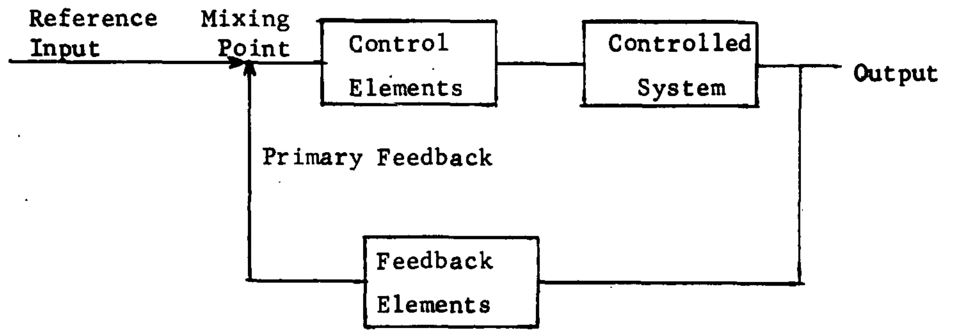


Fig. 3 - A typical feedback control system

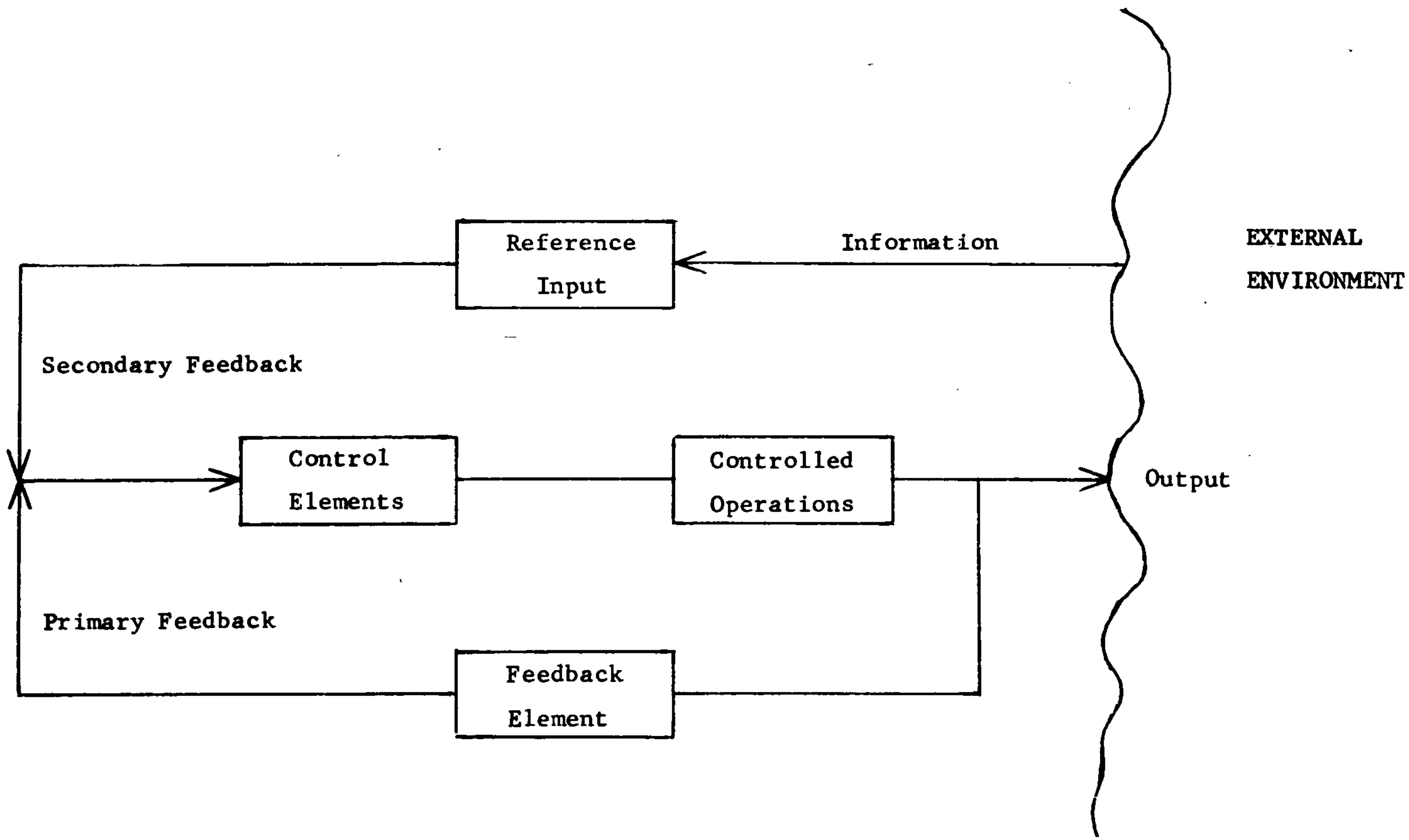


Fig. 4 - Control system with feedback from an external environment

of the feedback control system.* This has been applied to economic models, and perhaps Jay Forrester is most well known for his multivariable dynamic models.(15,16) A similar model has been used in "command and control research for the military and in management control system research for business.(17, 18)

The most common feedback control equation is

$$\frac{d^2y}{dt^2} + 2\xi\omega \frac{dy}{dt} + \omega^2 y = r(t)$$

where $\xi$ = damping ratio

$\omega$ = undamped natural frequency

This equation yields a sine wave or pure cyclical solution when $\xi = 0$. Figure 5a shows a step function for r(t) (the input) and the resulting value of y for various damping ratios is shown. Notice that if $\xi = 0$ the system oscillates from the former value, 0, to twice the value of r(t). This oscillation continues without any change of r(t). Increased damping ratios cause the solution to approach the value of 1 with less oscillation. For high values of $\xi$, however, the solution will very slowly change from 0 to 1. If a fast response to transient changes is needed; then a high value of $\xi$, exceeding those graphed, will change too slowly. But on the other hand, low values of $\xi$ will cause overshoot, that is, the function y will exceed 1.

Since this behavior in business operations causes additional costs (lost sales if the changes are too slow, periodic overproduction and underproduction if the changes are too fast--i.e., $\xi$ approaches 0), it

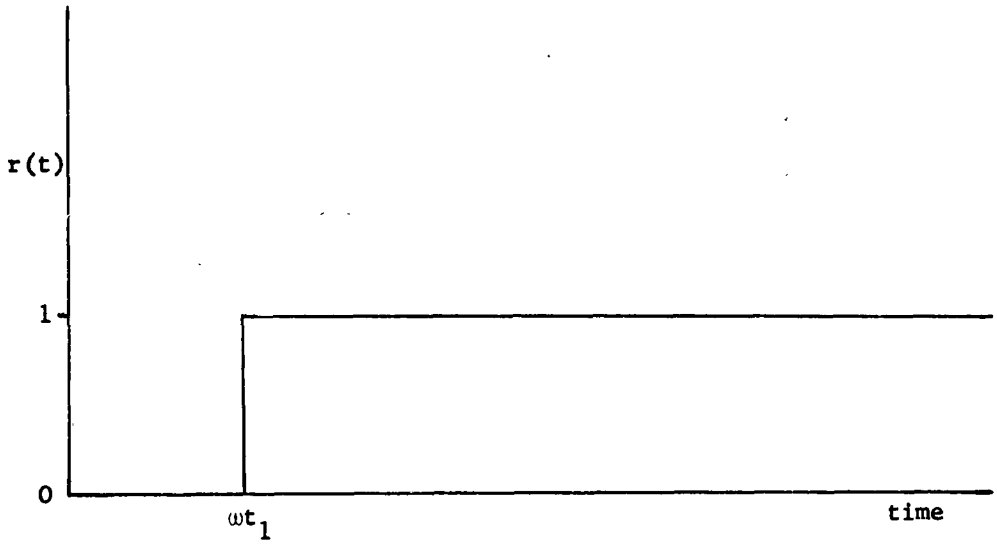


Fig. 5a - Unit step function in position $\omega t_1$

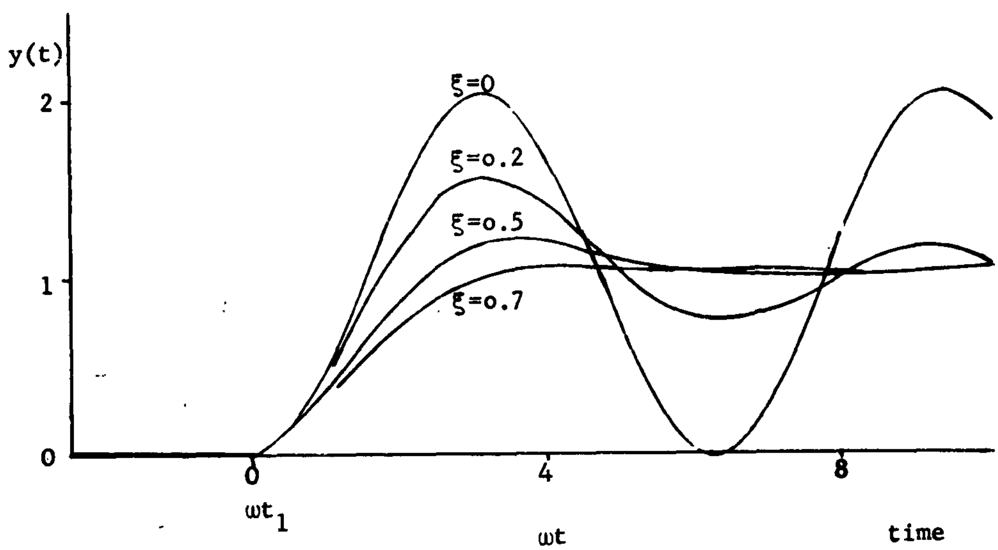


Fig. 5b - Transient response curves for various values of ξ is desirable to have some optimum response to minimize costs.

The damping factor, $\xi$, can take on negative values. When this occurs, the value of y will be periodic with a frequency $f = 2\pi\omega$ cycles per unit time. The amplitude will be continually increasing, depending on the value of $\xi$, and the system will be out of control. Generally there are some mechanical limitations to this process. One such limitation generally being an absolute lower and upper bound for the values of y. This function was not graphed.

The value of $\omega$ depends on the characteristics of the system. If $\omega$ itself is small, then the system will approach its steady state solution quickly. If $\omega$ is, for example 2 months, a larger value, then the cyclic solution will have a frequency of about one cycle per year.

If there is a delay in the feedback elements, this may have a stabilizing or destabilizing effect, depending on the phase relationship of the error signal to the output. Here again, some transient in the input signal can cause behavior similar to those illustrated above.

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